The LIEBE high-power target: Offline commissioning results

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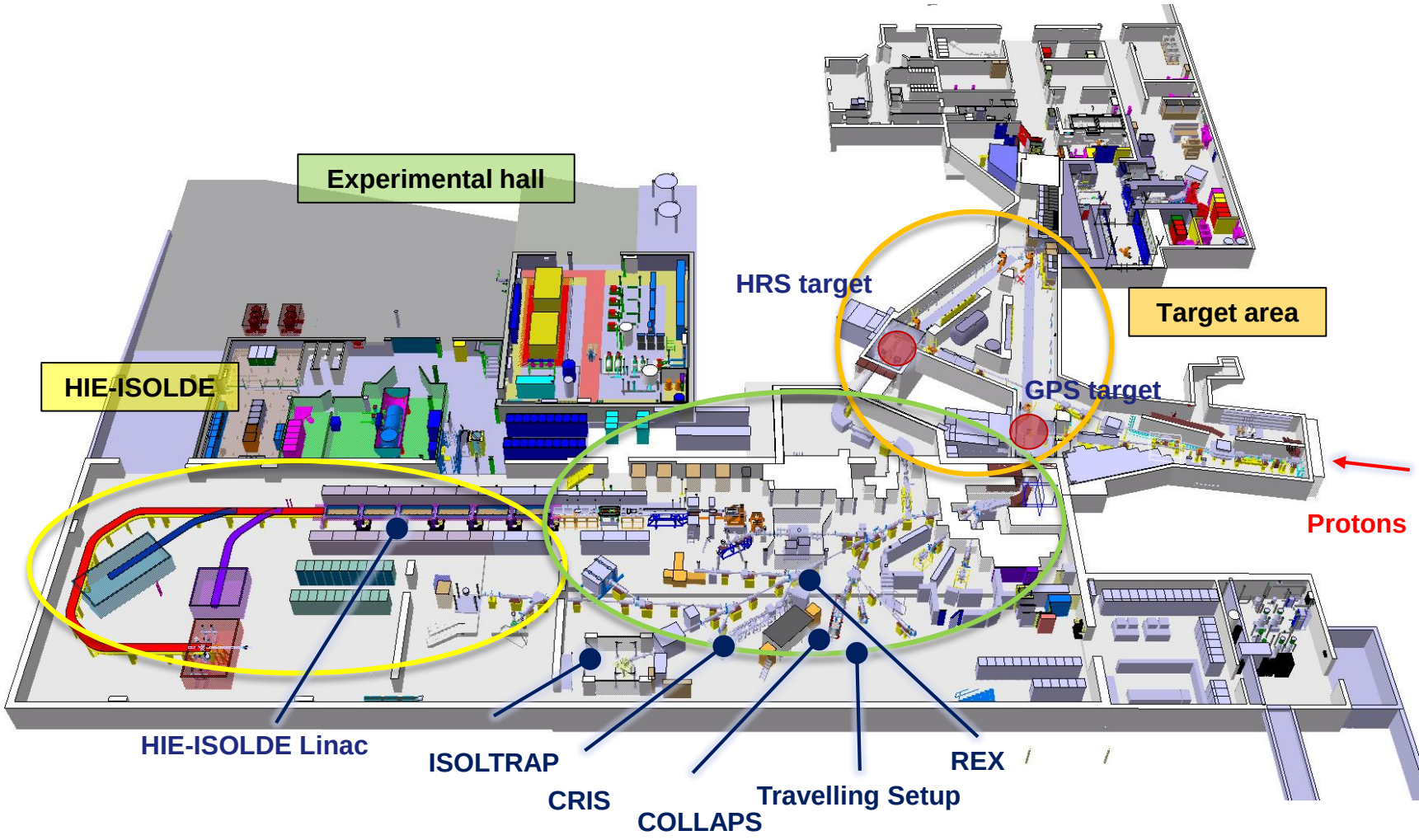
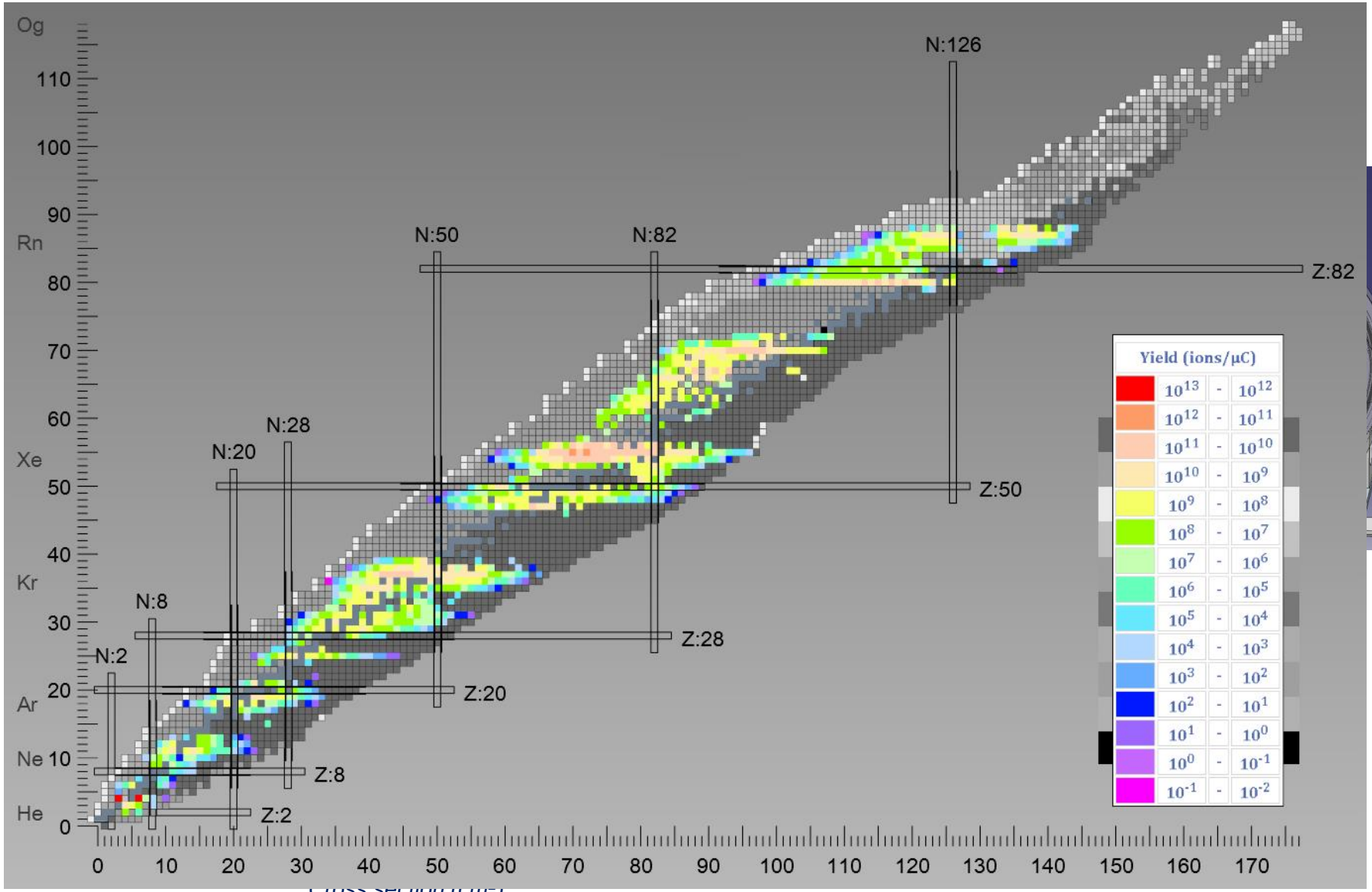
CERN
EN
ENGINEERING DEPARTMENT

Isolde hall layout



ISOLDE


Og
Rn
Xe
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He
110
100
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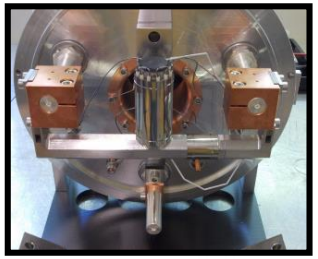
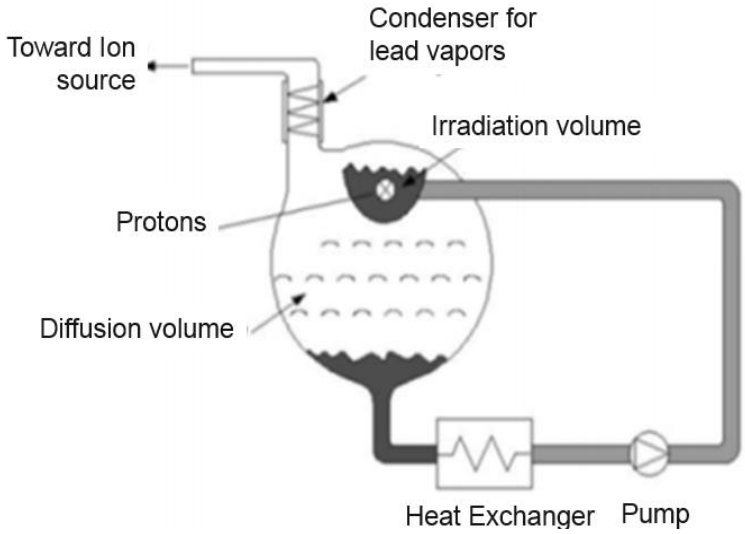
70
60
50
40
30
20
10
0
N:126
N:50
N:82
Z:82
N:28
N:20
Z:50
N:8
N:2
Z:28
Z:20
Z:8
Z:2
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Yield (ions/μC)
10^{13} - 10^{12}
10^{12} - 10^{11}
10^{11} - 10^{10}
10^{10} - 10^{9}
10^{9} - 10^{8}
10^{8} - 10^{7}
10^{7} - 10^{6}
10^{6} - 10^{5}
10^{5} - 10^{4}
10^{4} - 10^{3}
10^{3} - 10^{2}
10^{2} - 10^{1}
10^{1} - 10^{0}
10^{0} - 10^{-1}
10^{-1} - 10^{-2}
Cross section (cm²)

Introduction/Context

- High power target for exotic species



Long tradition of operation of molten targets at ISOLDE



Concept scheme, E. Noah et all, EURISOL-DS

$$i = \Phi . \sigma . N . \varepsilon_{target} . \varepsilon_{source} . \varepsilon_{sep} . \varepsilon_{transport}$$

Protons/pulse	Current (μA)	Energy (GeV)	Cycle length (s)	Average power (kW)
3.3×10^{13}	2.2	1.4	1.2	3.1
1×10^{14}	6.7	1.4	1.2	9.3
1×10^{14}	6.7	2.0	1.2	13.4

Possible update parameters of the proton beam sent to ISOLDE, R. Catherall et al 2017.

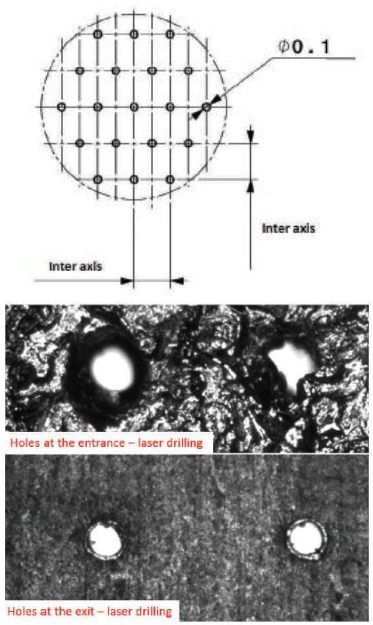
→ Lanthanum eutectic + SnCl molecular beam: Towards 100Sn beams at HIE-ISOLDE
T. Stora et al., EMIS 2018

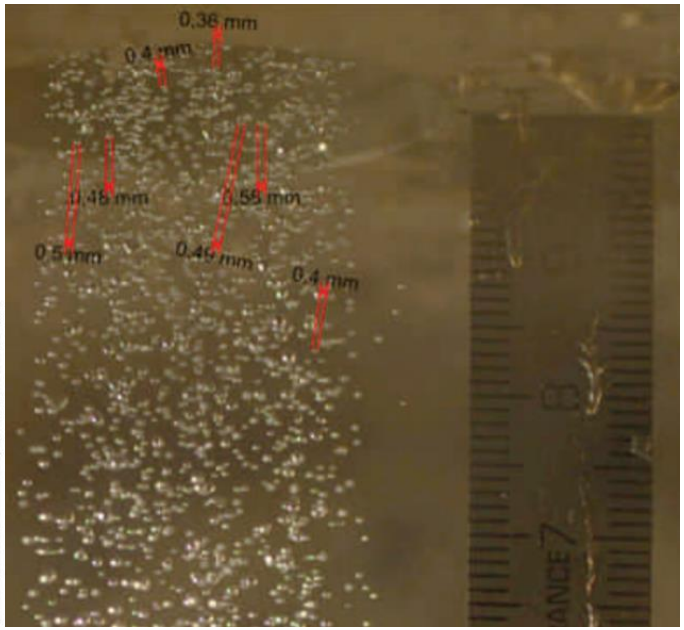
Concept → Prototype → Offline commissioning → Online tests

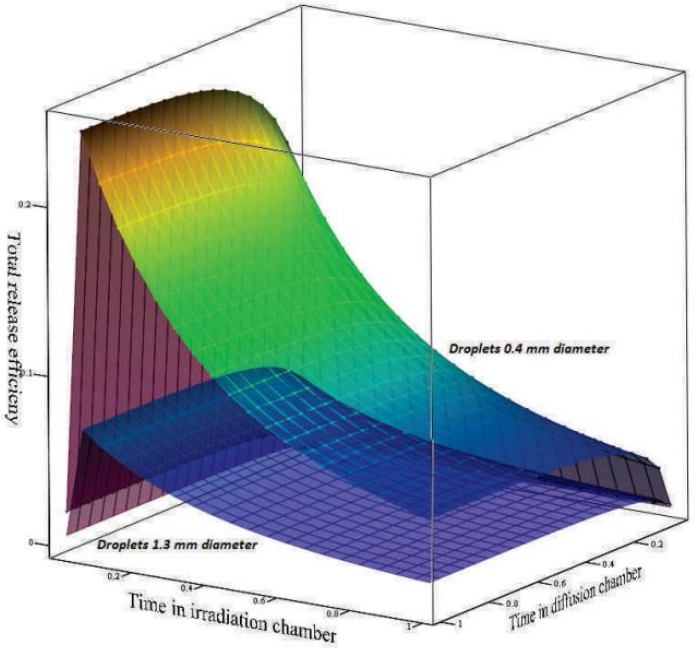
Introduction/Context

Concept

- LIEBE: LIquid Eutectic lead Bismuth for Eurisol
  - Target material: LBE
  - Operational temperature: [200-600]°C
  - Targeted isotope: ^{177}Hg (130ms half-life)
  - LBE Velocity preferred: **2 m/s ⟶ Q=0.13 l/s**
  - **Ø0.4 mm** droplets ⟶ factor **5** more release





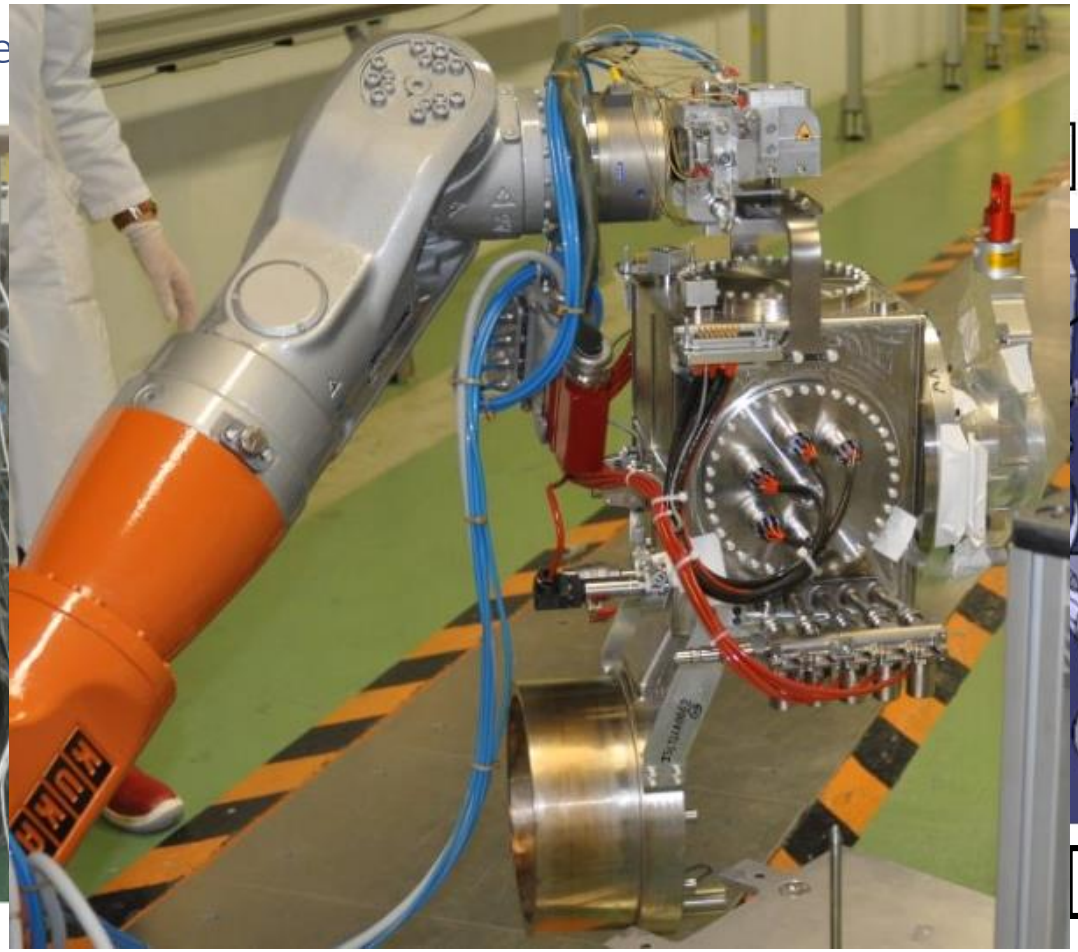


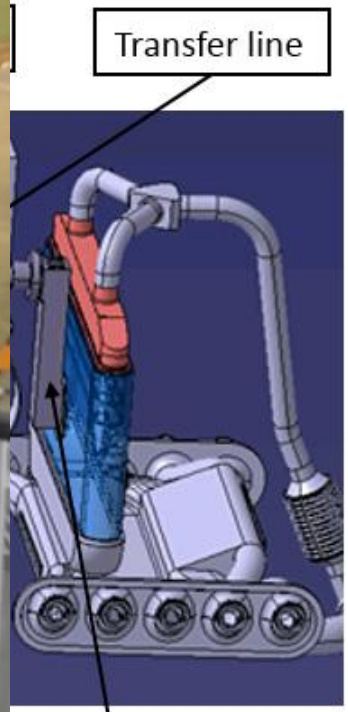
Images from Melanie Delonca CERN Ph.D thesis

LIEBE prototype design & completed assembly

Concept → Prototype

- The target:
  - Compatible



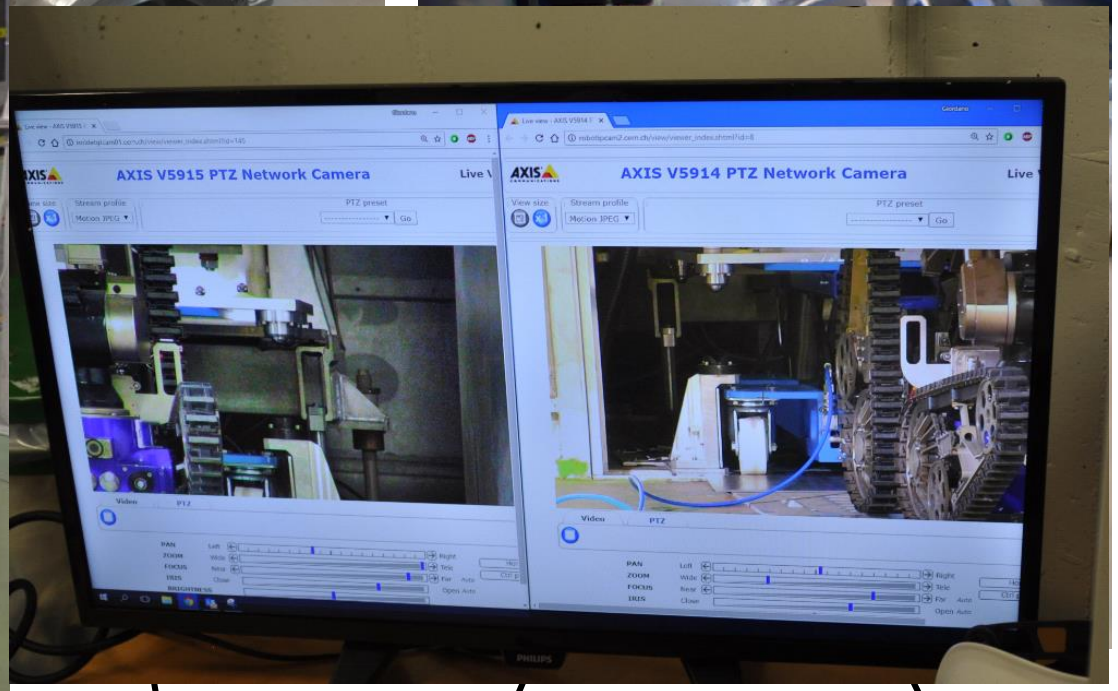


LIEBE prototype design & finished assembly

- The EM pump:

University of Latvia Institute of Physics

Concept → Prototype



Coupling rails

Alignment table

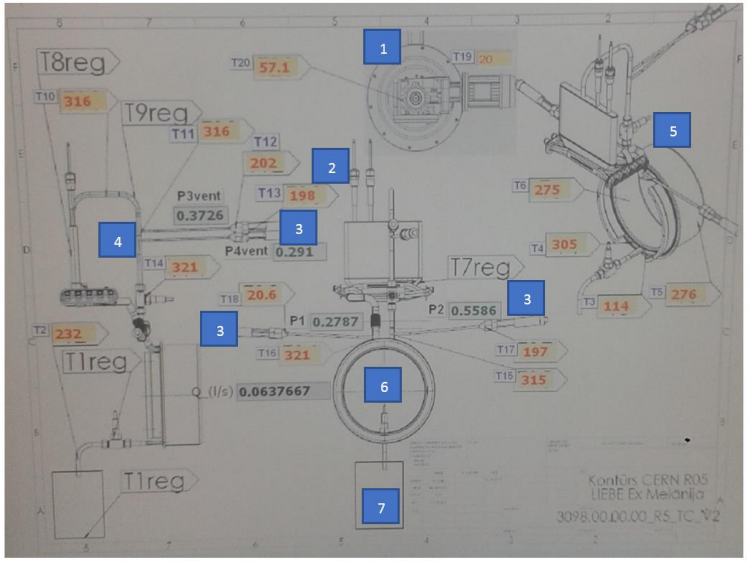
Dedicated trolley

Offline commissioning: Flow assessment

Concept → Prototype → Offline commissioning

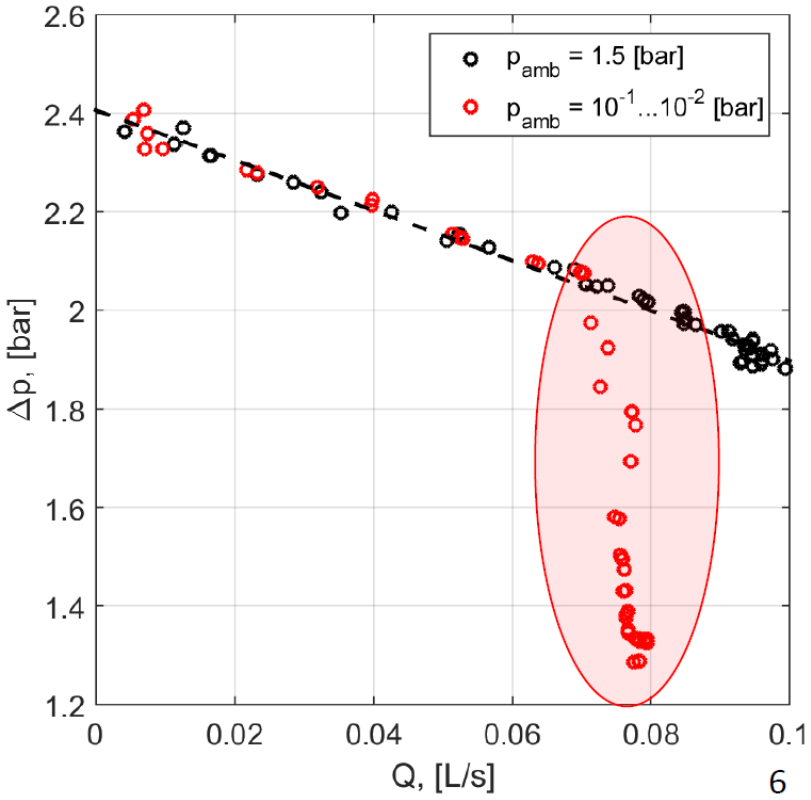
- Test objectives:
  - Operate in the absence of cavitation
  - Reach the desired flow for release optimization (0,13L/s)

Increased diameter: Ø10mm ➡ Ø16mm



1- EM pump
2- Level sensors
3- Manometers
4- Venturi tube
5- Mechanical valve
6- Channel connected to EM pump
7- LBE tank

Screenshot of the tests setup

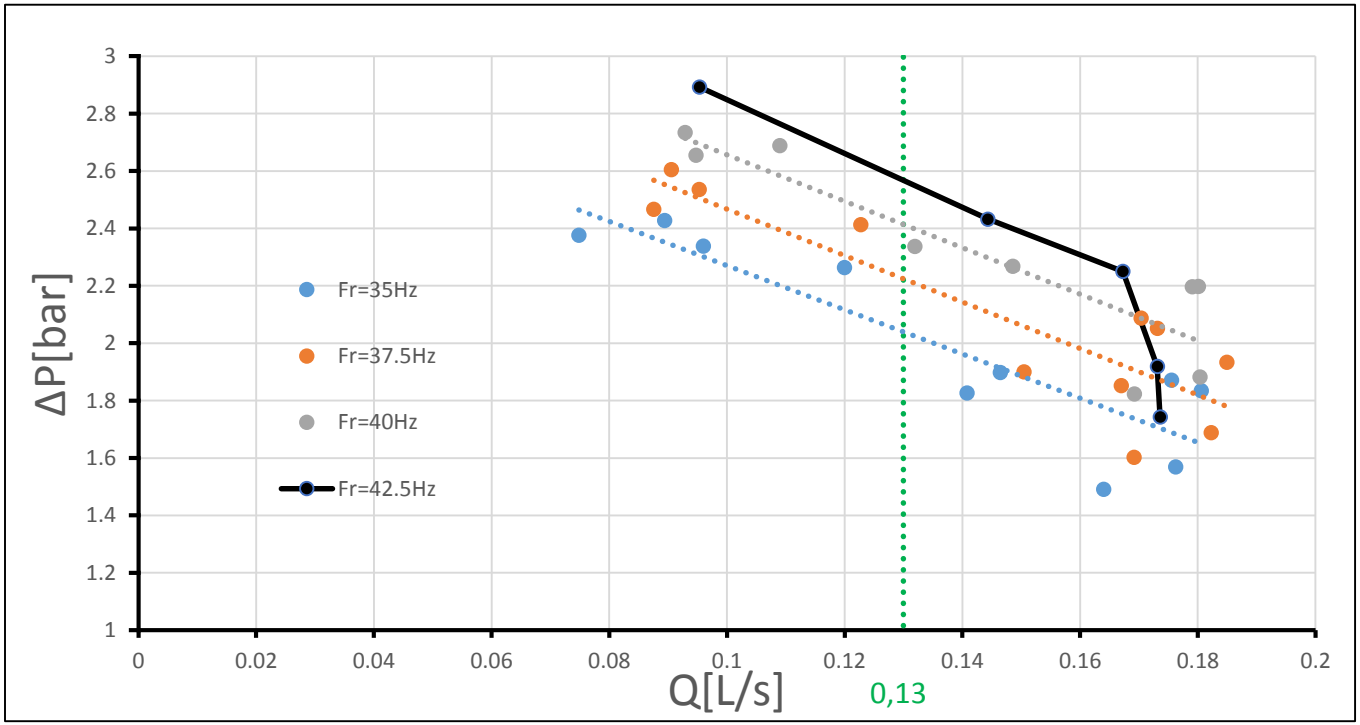


Flow assessment in previous tests at IPUL

Offline commissioning: Flow assessment

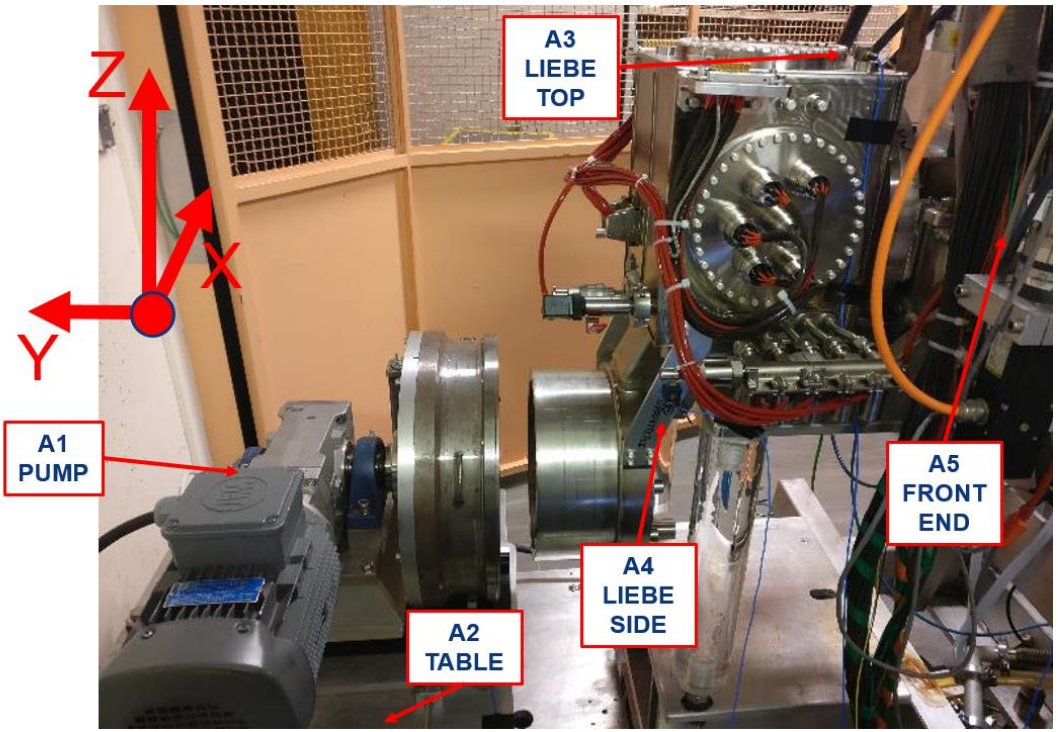
Concept → Prototype → Offline commissioning

- Results:
  - Drift observed between measurements due to clogging of the sensors
  - LBE oxide formation in contact with air

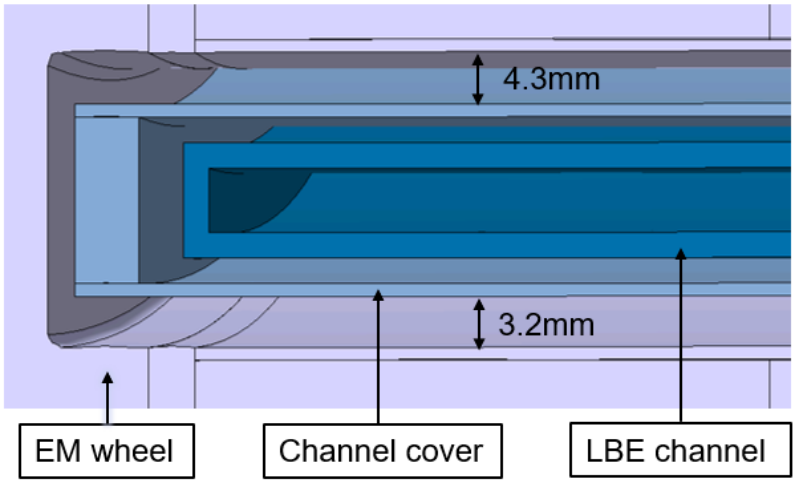


Offline commissioning: Alignment/vibration tests

- Vibration tests: Concept → Prototype → Offline commissioning
  - Check vibration transmission
  - Evaluate the level of vibration for each rotational frequency



Test setup after alignment



Empirically measured maximum distances in case of perfect alignment

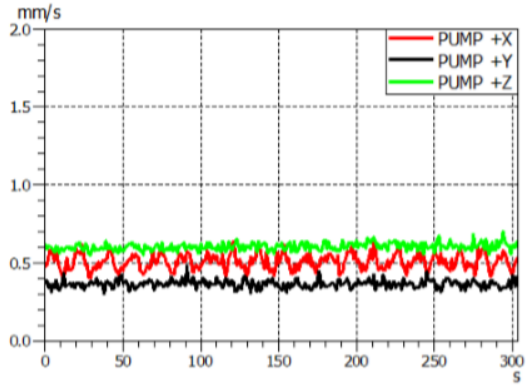
Offline commissioning: Alignment/vibration tests

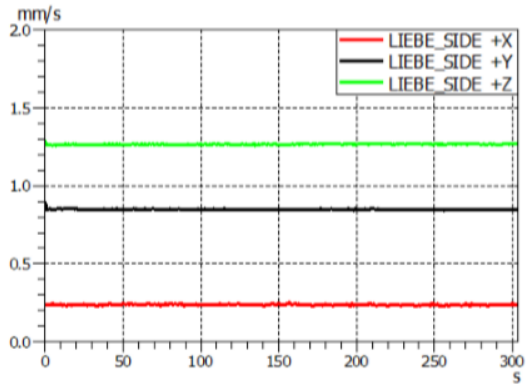
- **Results:**

Concept → Prototype → Offline commissioning

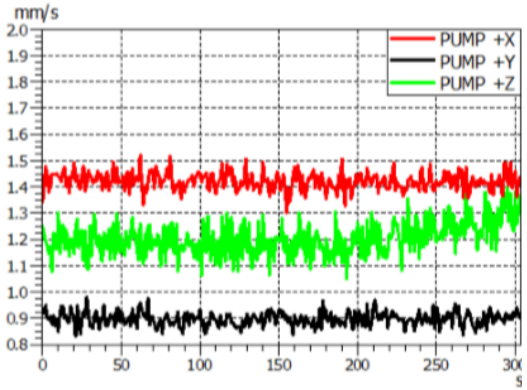
  - Sudden vibration increase due to natural resonant frequencies

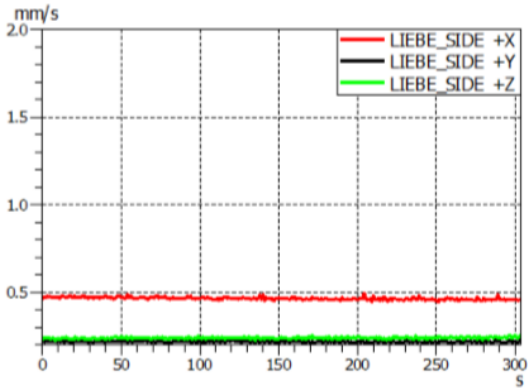
	PUMP			LIEBE_SIDE (Uncoupled)			LIEBE_SIDE (Coupled)		
	+X	+Y	+Z	+X	+Y	+Z	+X	+Y	+Z
Baseline	0.20	0.19	0.19	0.06	0.05	0.04	0.05	0.05	0.04
10Hz	0.83	0.54	0.47	0.05	0.05	0.04	0.52	0.17	0.22
20Hz	0.54	0.39	0.64	0.06	0.05	0.04	0.24	0.85	1.27
30Hz	0.88	0.79	1.13	0.06	0.05	0.04	0.45	0.39	0.19
40Hz	1.44	0.92	1.19	0.07	0.05	0.04	0.48	0.22	0.25
50Hz	4.28	1.76	1.41	0.05	0.05	0.05	0.73	0.27	0.25





Rotor Fr= 20Hz





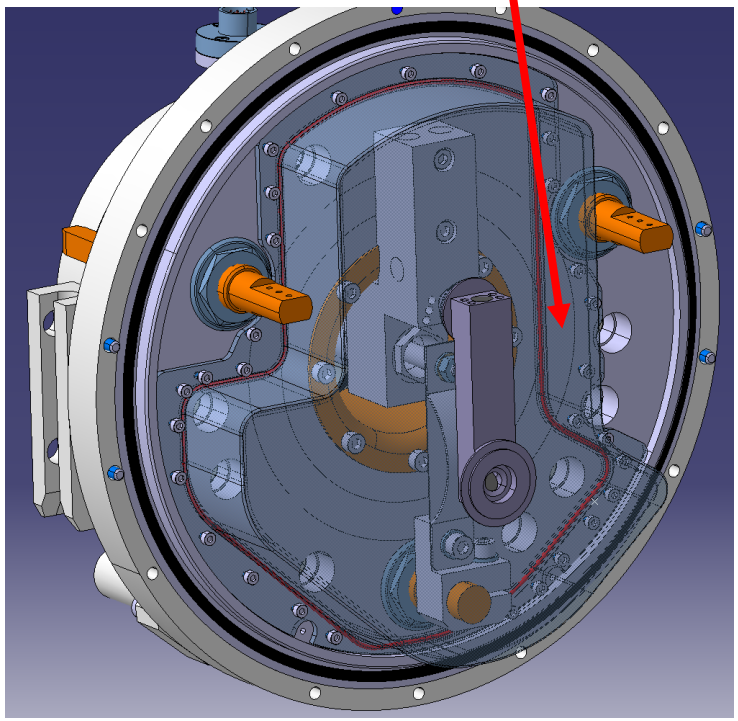
Rotor Fr= 40Hz

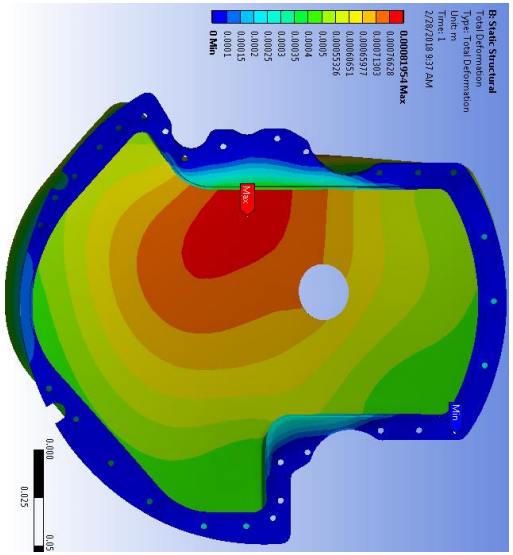
- Good/satisfactory levels for operational frequencies of LIEBE
- Addition of an accelerometer to monitor the vibration throughout operation with LBE

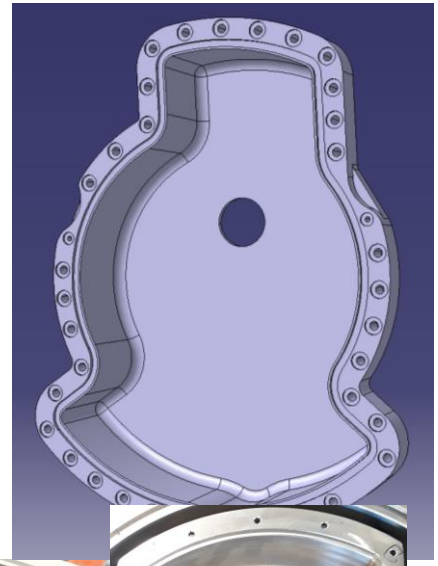
Offline commissioning: Leak issue

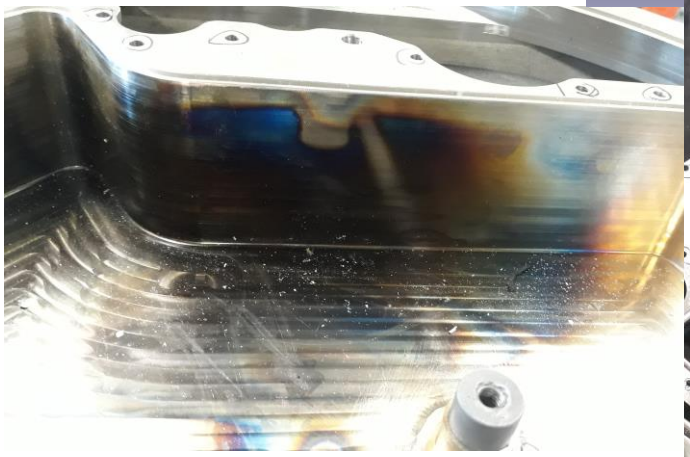
Concept → Prototype → Offline commissioning

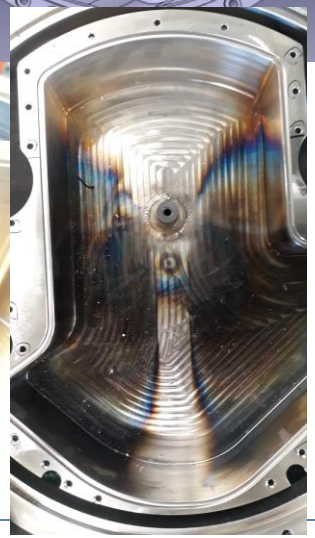
- Leak emergence:
  - Appropriate vacuum level with cold target
  - Leak appearing when heating up the ion source to 1700 ºC





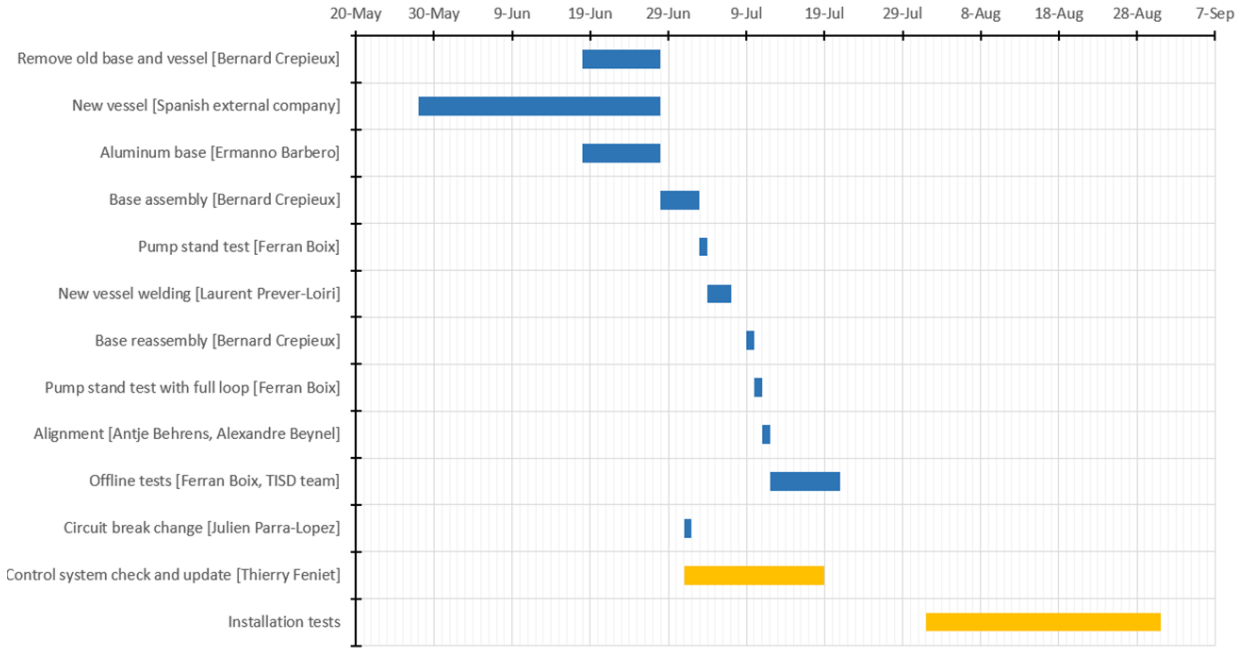


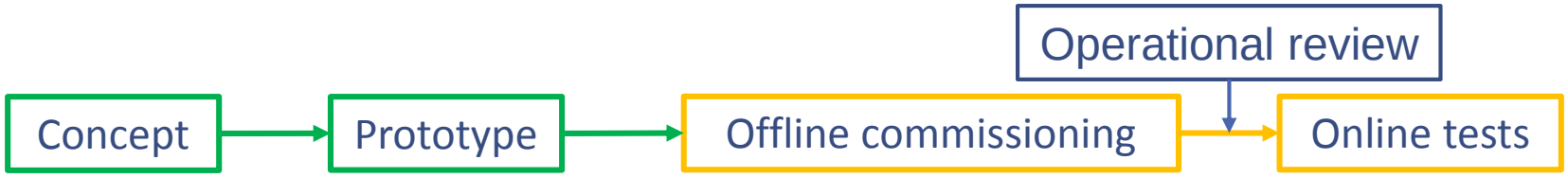




Offline commissioning: Remaining tests

- Full operation of the loop with molten LBE in an offline mass separator:
  - Thermal control
  - Safety measures:
    - Pressure sensor
    - Accelerometer
  - Mass scans





Conclusions

- Prototype and offline commissioning:
  - Flow developed by the EM pump : within specification
  - Vibration : within specification
  - Target handling & optimization : within specification

  →New base design for leak-tight confinement vessel
- Remaining full operational tests in an offline separator
- Online tests foreseen for the last run at ISOLDE

Acknowledgements

EN-STI-RBS : Bernard Crepieux, Andres Vieitez, Melanie Delonca, Thierry Stora, TISD group, Ana Paula Bernardes, Ermanno Barbero, Beatriz Conde Fernandez
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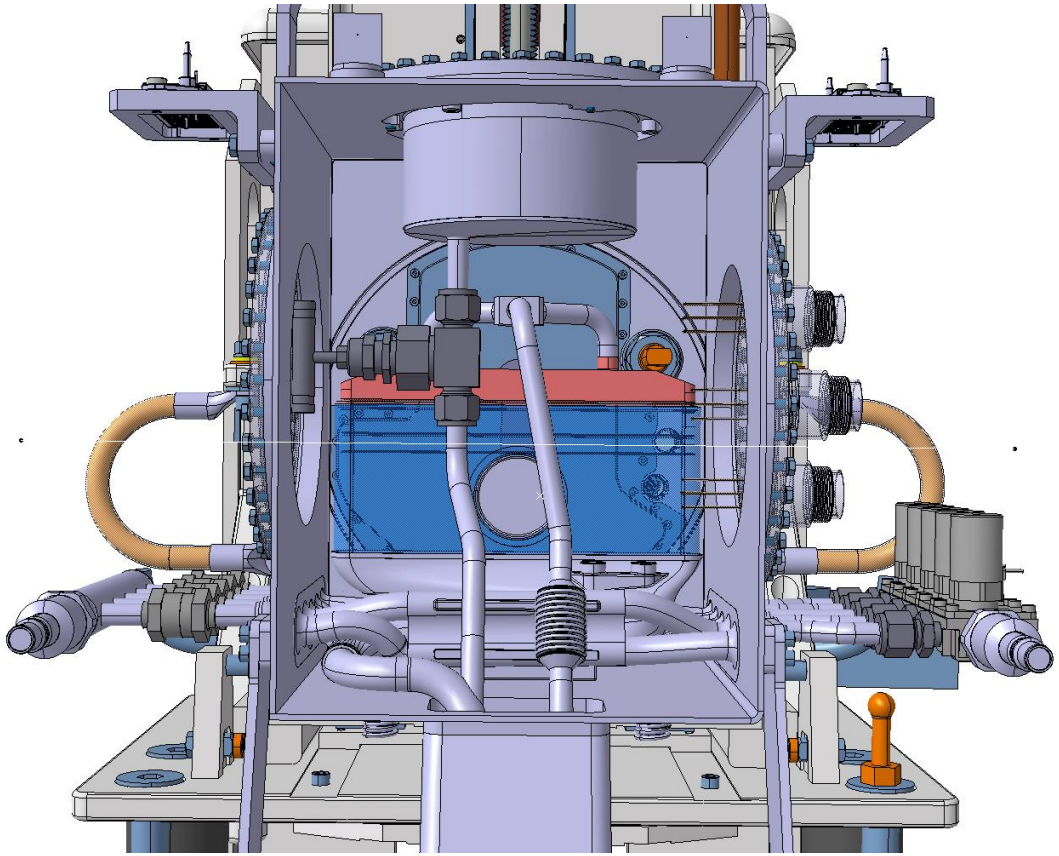
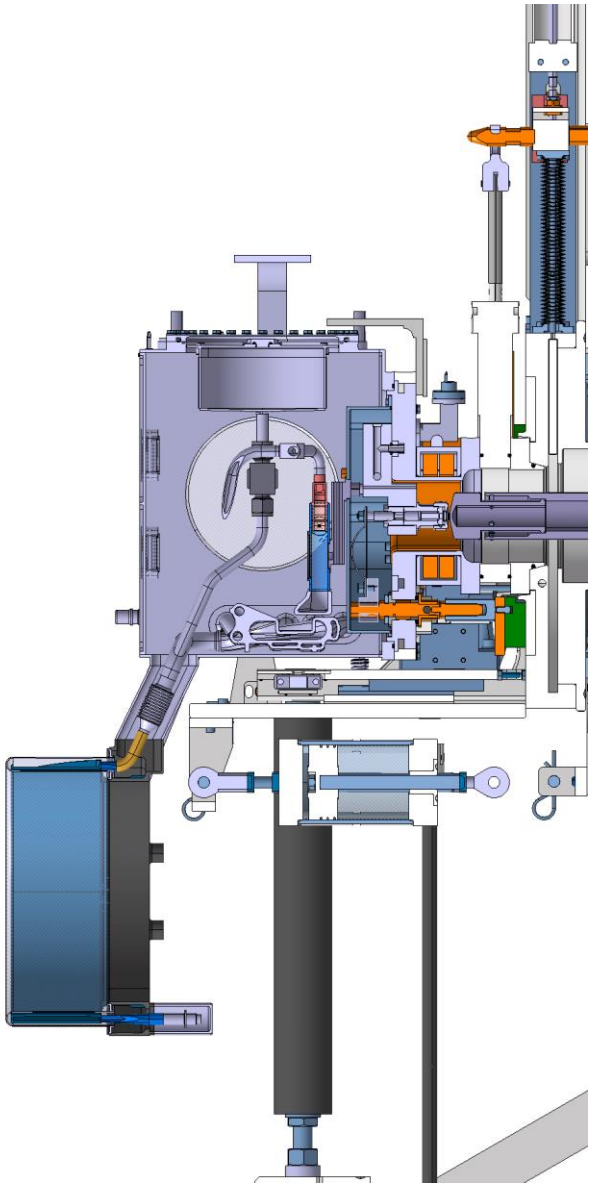
EN-MME : Laurent Prever-Loiri, Lukasz Jerzy, Vincent Barozier
EN-SMM : Thierry Feniet, Antje Behrens, Alexandre Beynel
EN-HE : Jean Louis Grenard
BE-OP : Pascal Fernier
SINP, IPUL, SCK.CEN : Susanta Lahiri, Kalvis Kravalis, Donald Houngbo,

Thank you for your attention

Backup slides

The main loop part

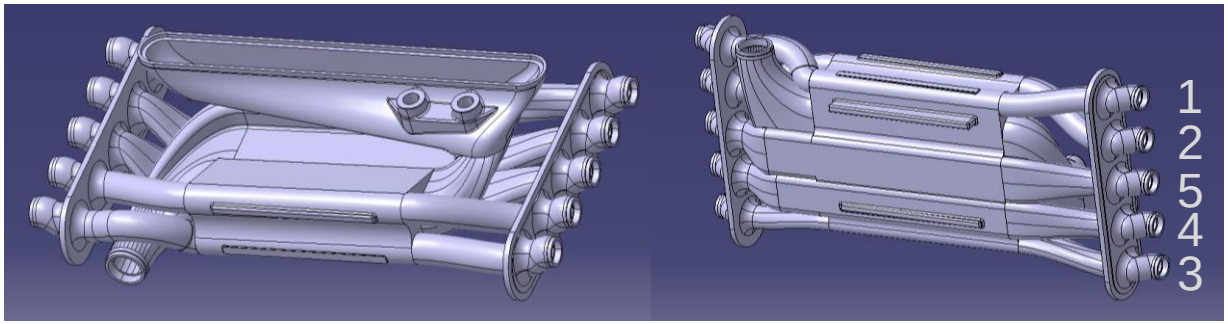




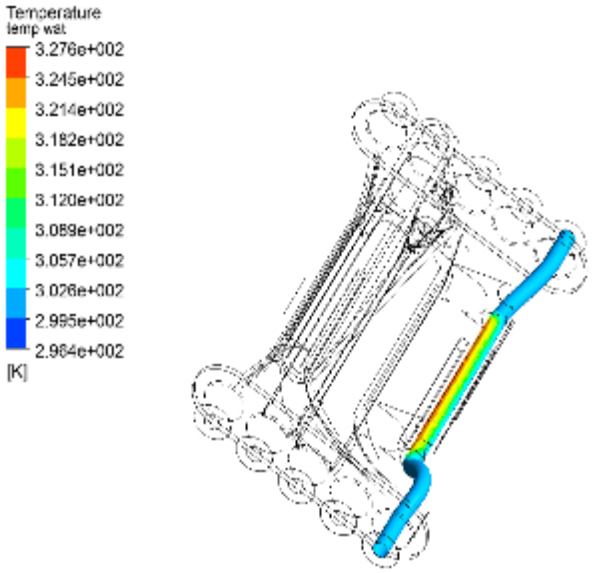
- Filling tank
- Heat Exchanger (HEX)
- Irradiation & diffusion chamber
- Hypertaks/feedthroughs
- Water connectors
- Electrovalves
- Bellows
- Extraction line and ion source -> standard VADIS ion source

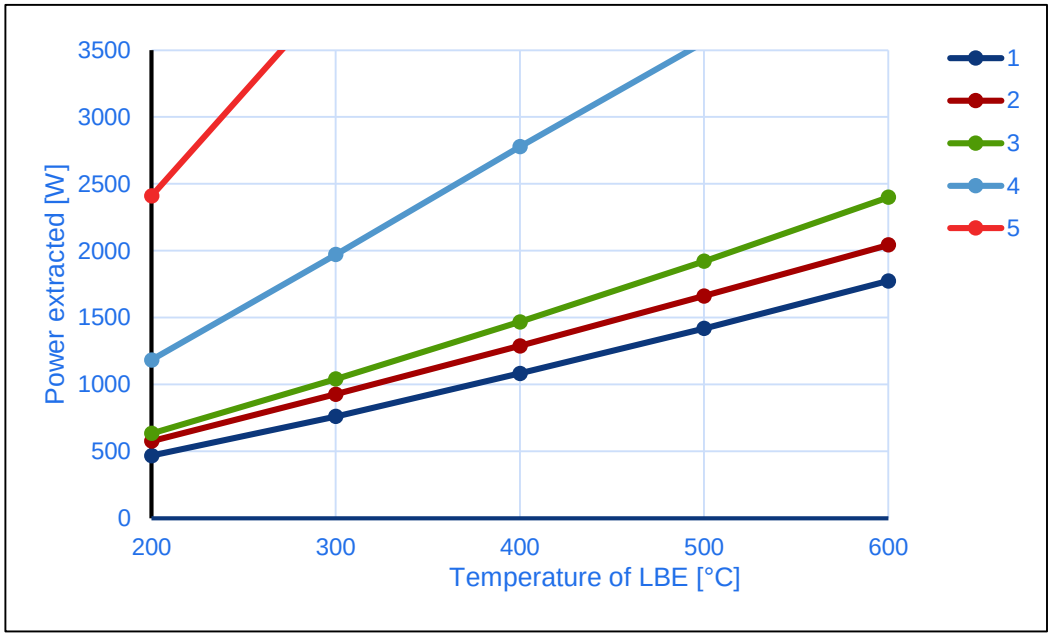
LIEBE: Heat Exchanger

- 5 LBE temperatures (200-600degC)
- CFX Calculations of the heat exchanged for every channel



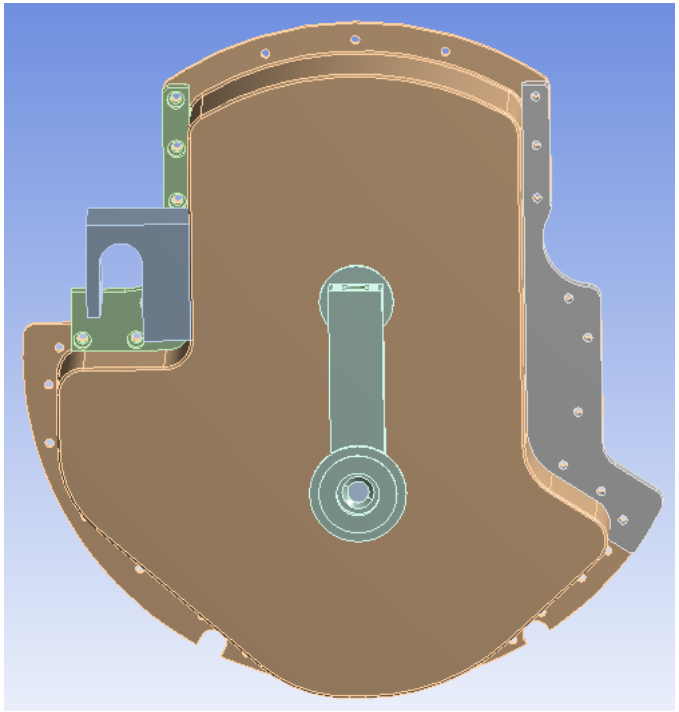
3D printed steel Heat Exchanger

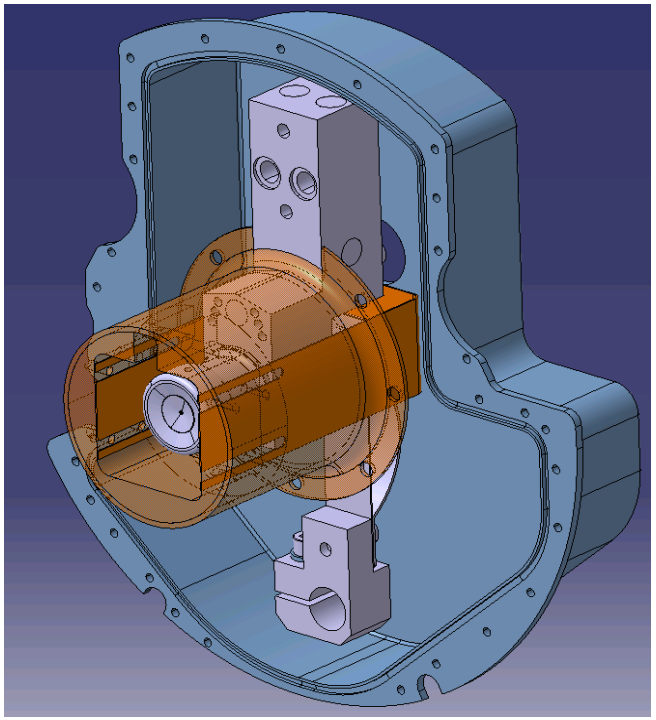




Offline commissioning: Leak issue

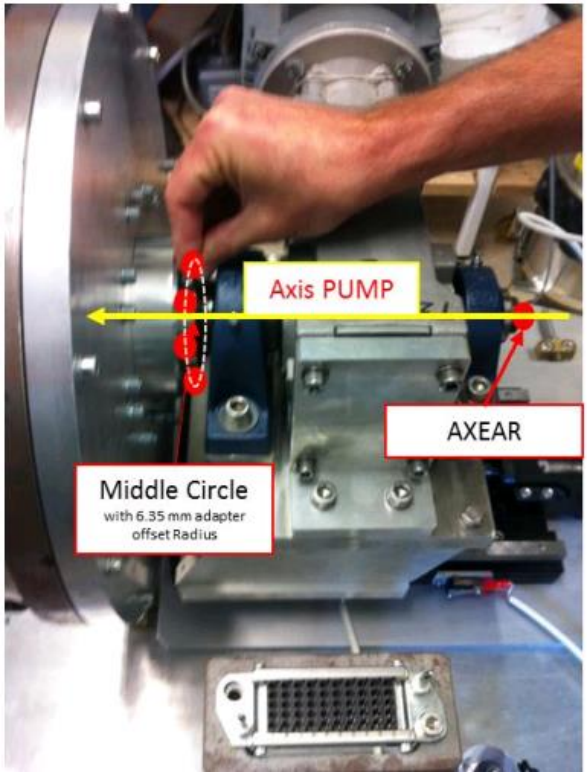
- Attempts to solve it:
  - Increasing sealing pressure
  - Shielding the ion source
  - Only able to operate the source up to 1900 ºC



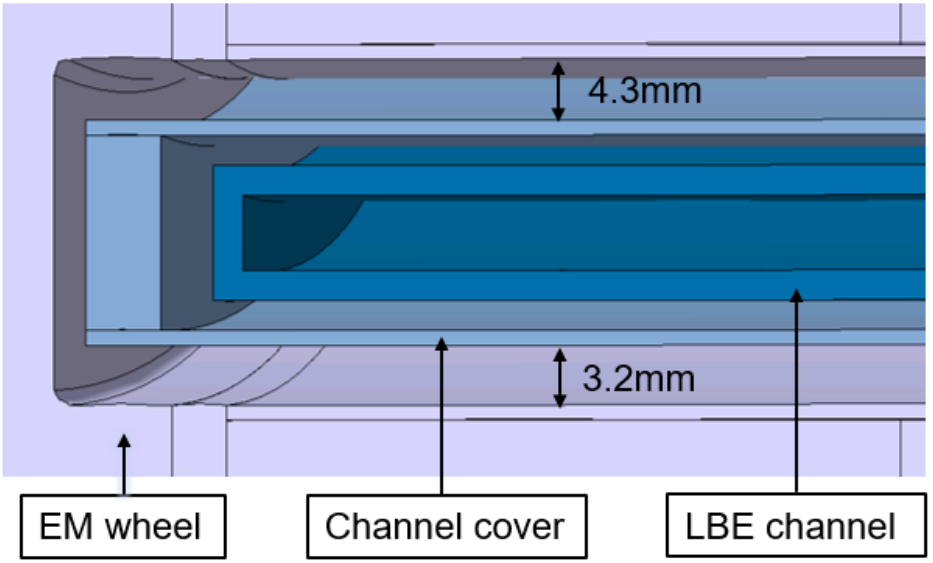


Offline commissioning: Alignment/vibration tests

- Alignment tests:
  - Cylinder axis and pump axis are on the same line within 0.1mm

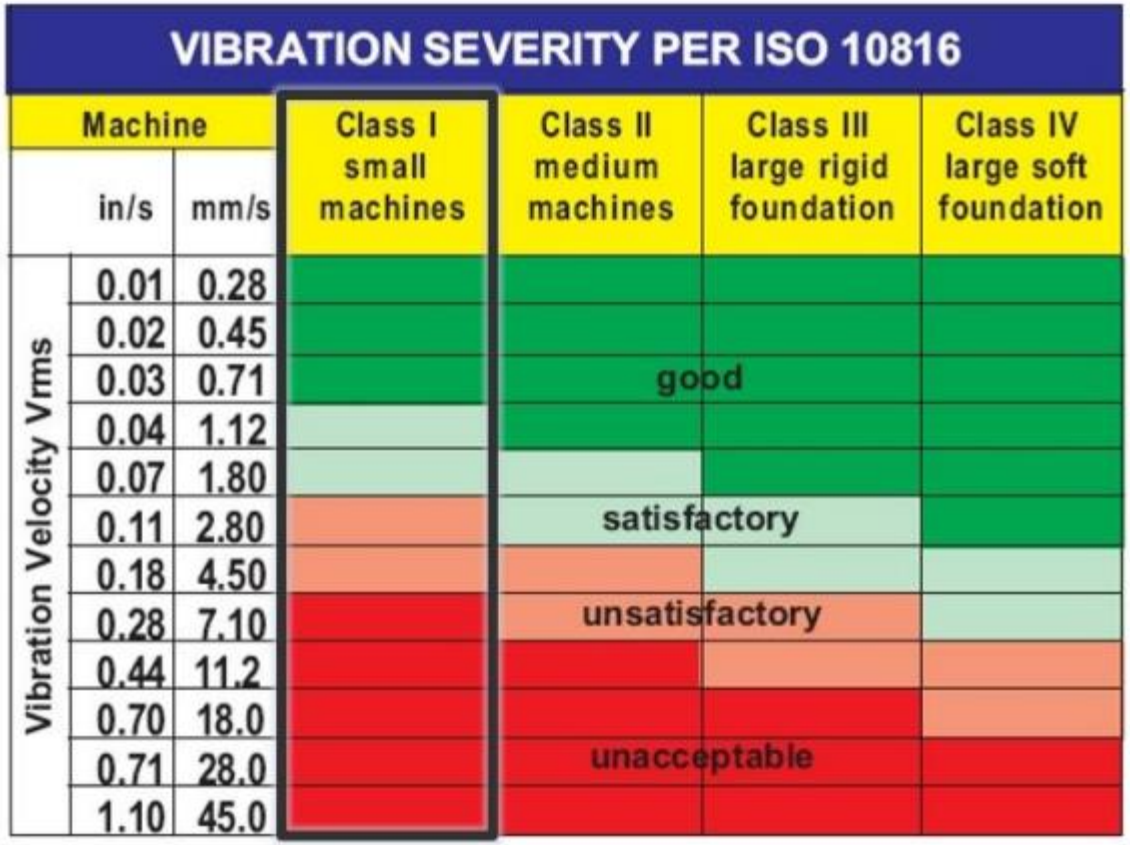


Measurement of the EM pump axis

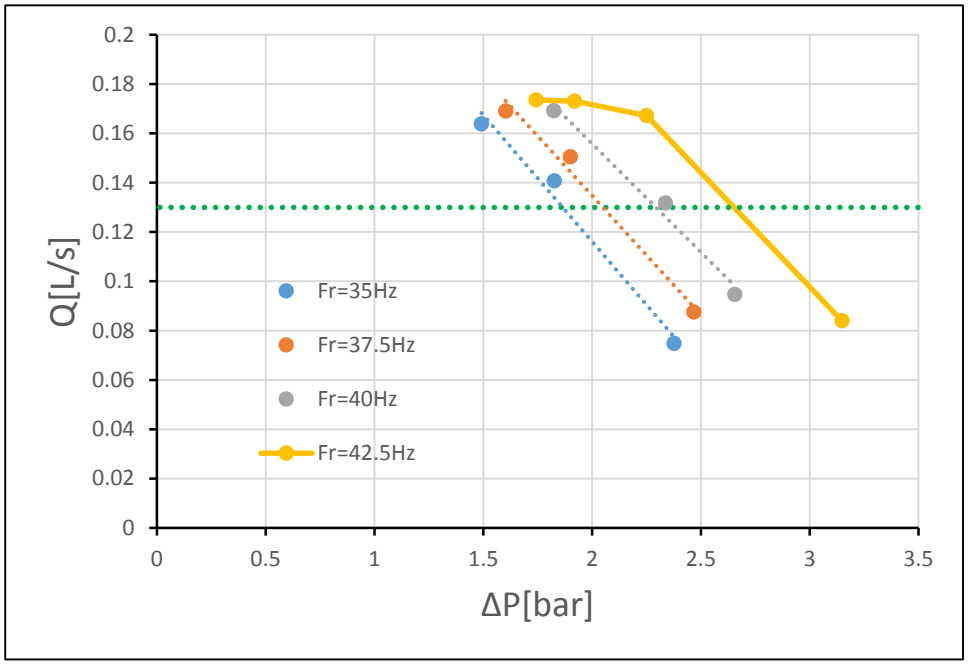


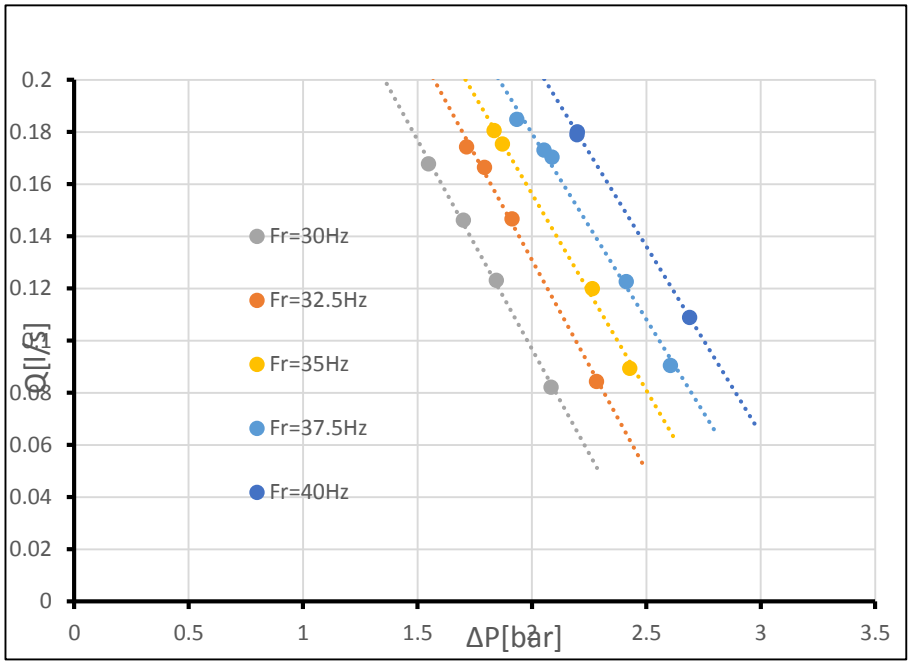
Best fit distances between EM pump and target

Offline commissioning: Alignment/vibration tests



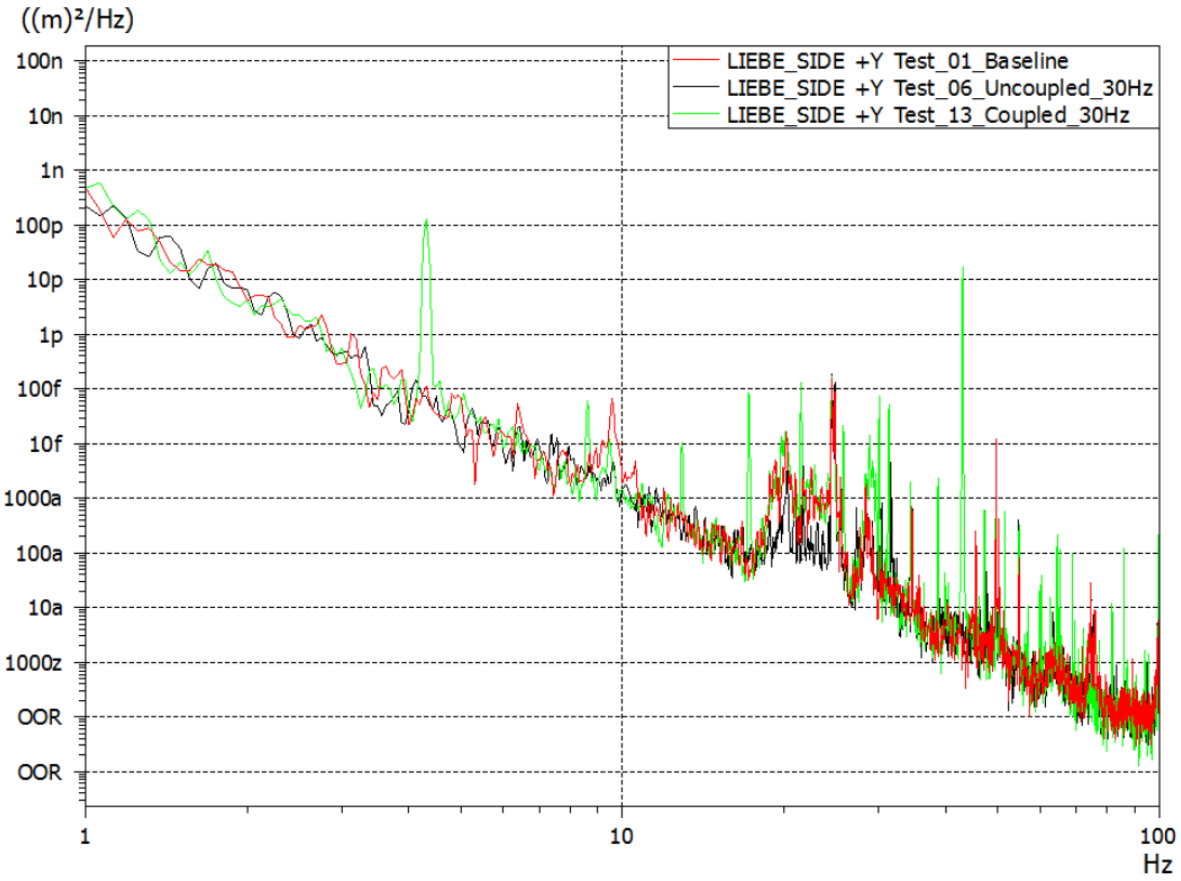
Offline commissioning: Flow assessment





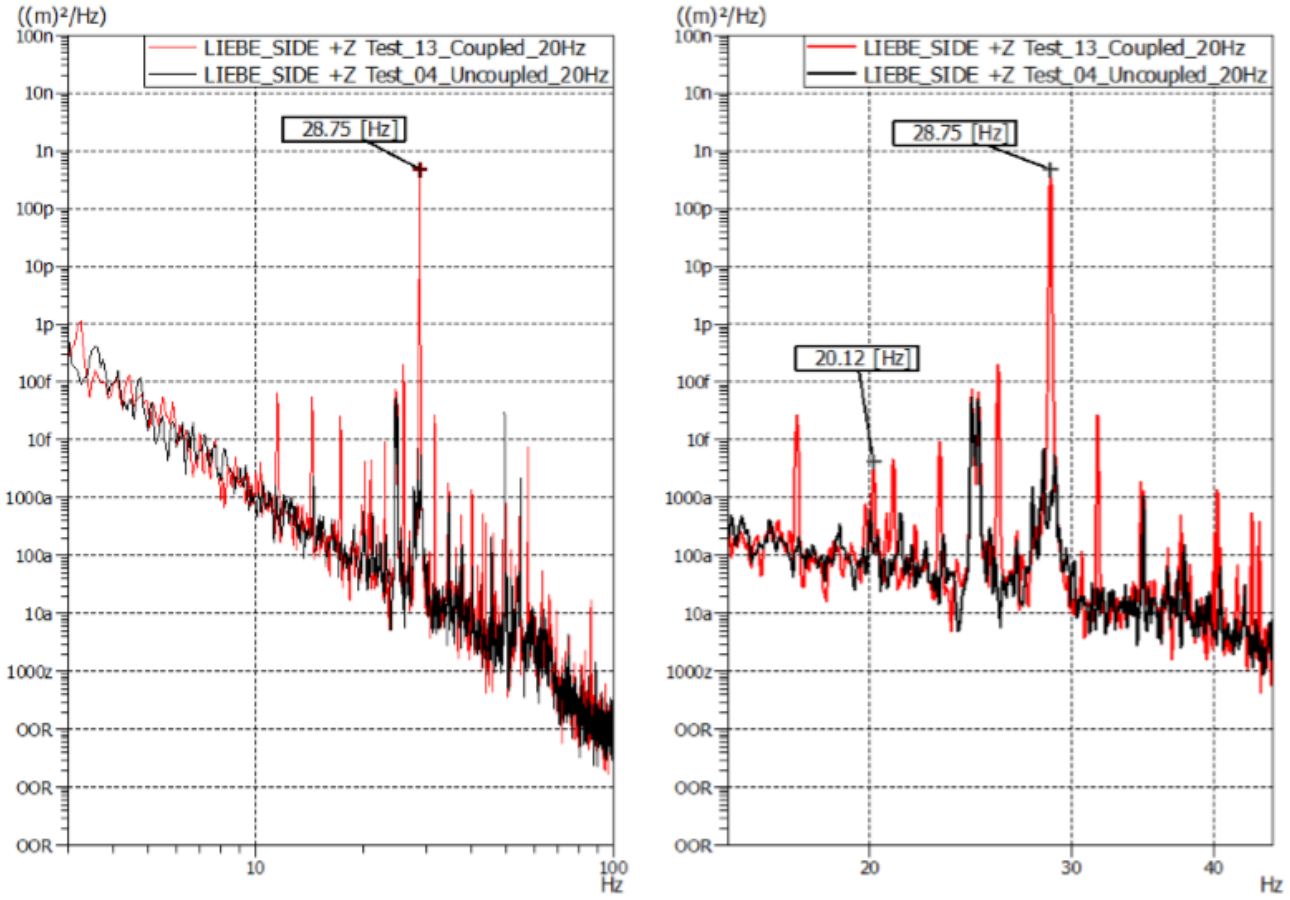
Offline commissioning: Alignment/vibration tests

- Results:



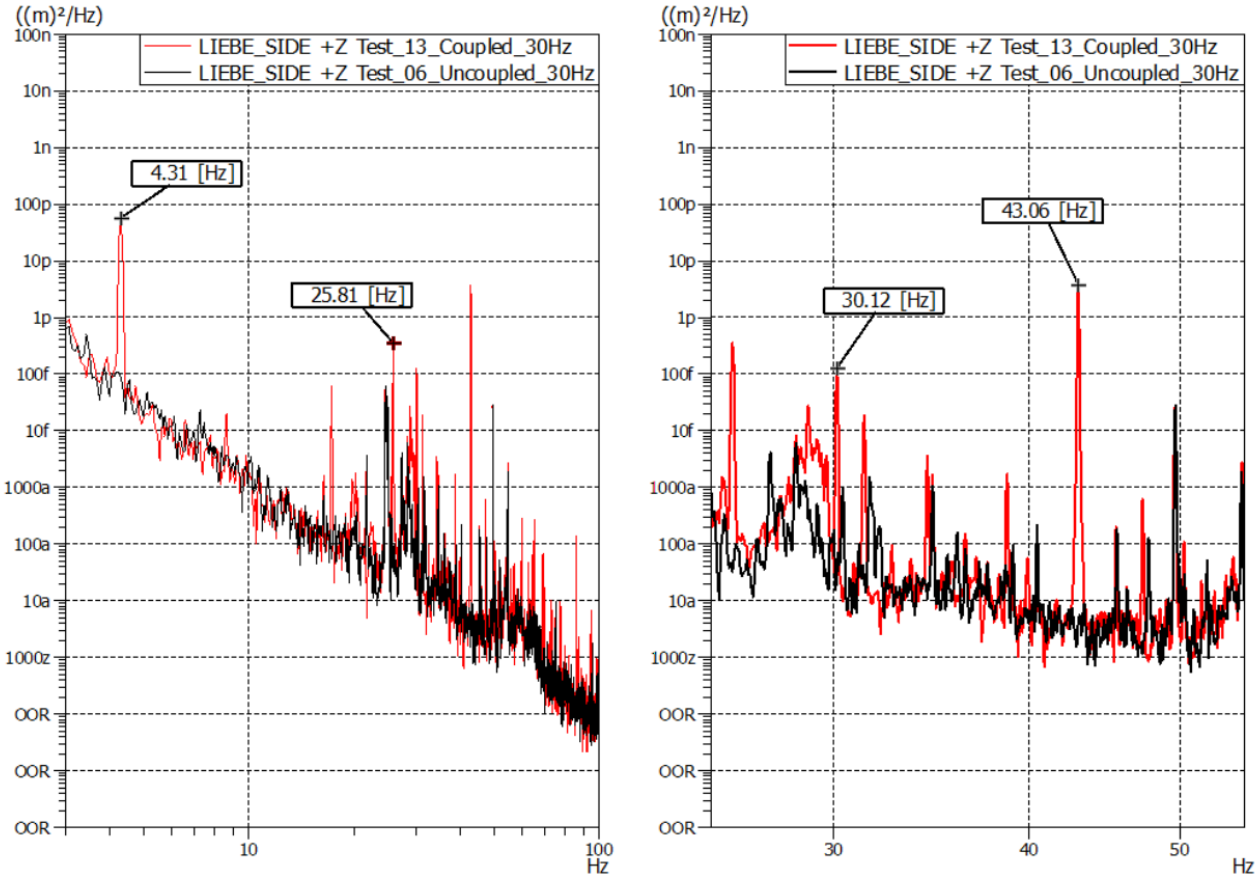
Displacement Power Spectral Density comparison, Rotor Fr=30Hz, EM Wheel Fr= 4,11Hz direction +Y

Offline commissioning: Alignment/vibration tests



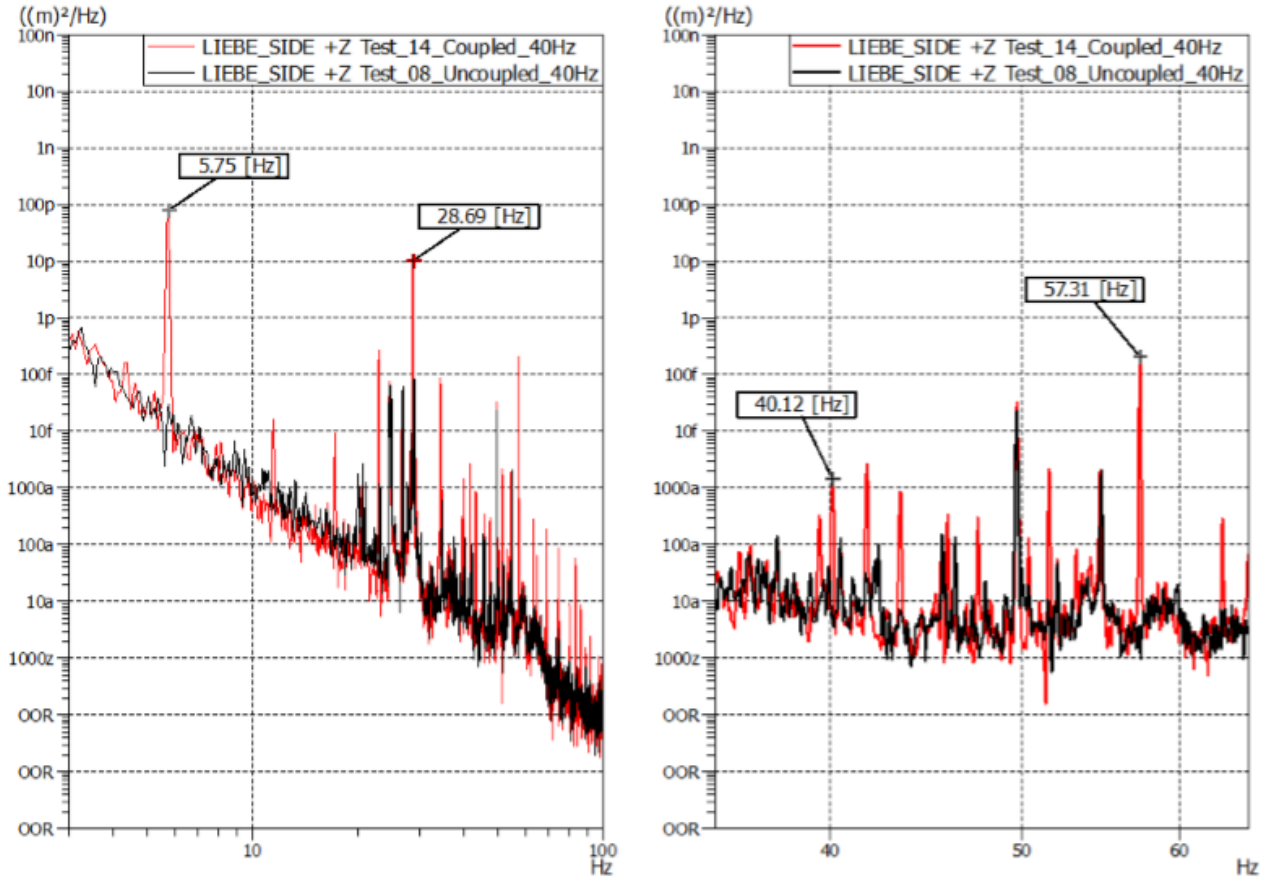
Displacement Power Spectral Density comparison, Rotor Fr=20Hz, EM Wheel Fr= 2,75Hz direction +Z

Offline commissioning: Alignment/vibration tests



Displacement Power Spectral Density comparison, Rotor Fr=30Hz, EM Wheel Fr= 4,11Hz direction +Z

Offline commissioning: Alignment/vibration tests



Displacement Power Spectral Density comparison, Rotor Fr=40Hz, EM Wheel Fr= 5,48Hz direction +Z